Notes from JHD analysis of some event clusters in Europe

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We summarize JHD results for event clusters in Europe analyzed with the view of defining reference events.
Each event cluster was defined by one or more reference events from the REF1.0 event list. Most of the clusters include a small number of events that were recorded at primarily local and regional distances. Paths to stations at close distances may have large spread in azimuth. For example, if the diameter of the event epicenters in a cluster is about 50 km a station at 50 km from the center of the clusters could have azimuths spanning an azimuth of 60 degrees of more and lengths of the paths may vary with a factor of three or more. The assumption in the JHD that travel time corrections for a given station are stationary may be violated in such cases. Stations with paths less than 5 times the cluster diameter are therefore, as a rule, omitted in the JHD (the factor 5 is referred to as ray spread parameter). In order to retain data sufficient for convergent JHD results events had to be removed, therby reducing the cluster diameter, from several of the European event clusters. Furthermore, the ray spread parameter had to be reduced to 3 in some cases.

CRITERIA FOR CANDIDATE REFERENCE EVENTS

Events are considered as candidate reference events of GT 5 category if (1) the estimated semi-major axis of the error ellipse (90%) < 5 km and (2) the distance to the nearest the reference events used to constrain the JHD of the cluster < 5 km.

SUMMARY OF RESULTS

Table 1 summarizes results 11 event clusters (Analyses were also attempted for a cluster in the Pyrenees, and three clusters in the Dead Sea regions, but did not yield converging solutions due to insufficient data). Table 1 gives for each cluster the number of events and the number of reference events used to constrain the JHD. The table also lists the number of stations at distances < 20° and > 20° used in the JHD and for which path corrections were estimated.
The effect on the geometry of epicenters of the JHD as compared with the single event determinations are described be two parameters in the table: the diameter defined as the maximum distance between any pair of events and the standard error of the distance from the center of the cluster. For 5 of the 11 clusters there is a clear reduction in the diameter, which varies between about 10 - 50 km. For 7 of the 11 clusters the standard error in epicenters was reduced by the JHD. The accompanying figures show the relative JHD epicenters of the events in each cluster. Table 1 also gives the percentage of arrivals rejected in the three steps of the JHD processing, which is typically around 5%. Finally, the table also lists the number of events with the semi major axis of the error ellipse, < 5 km and the number of events that also are within 5 km of the nearest reference event used to constrain the JHD.
It should be noted that the reference event of the Italian cluster in Umbria-Marche is about 10 km from the epicenter reported by Amato et al (1998), which was based on data from four close stations. The epicenters of three other events reported by Amato et al (1998) had similar off-sets relative to the JHD solutions. Until this discrepancy has been resolved the candidate reference events for the Umbria-Marche sequence has to wait consideration to be promoted.

Table 2 lists candidate reference events that meet the two criteria above. Events of the cluster at Lubin, Poland are not included as there are already 9 reference events from this cluster. Also, only the 10 most well recorded events are listed in the table, which for each event also give error ellipse, number of defining phases (only first arrival P used), and azimuthal gap.

REFERENCE

Amato, A., Azzara, R., Chiarabba, C., Cimin, G.B., Cocco, M., Di Bona, L., Margheriti, S., Mazza, F., Selvaggi, G., Basili, A, and E. Boschi, (1998), The 1997 Umbria-Marche, Italy, earthquake sequence: a first look at the main shocks and aftershocks, Geophys., Res., Letters, 25: 2861-2864.

Table 1: Summary of JHD Results

Cluster	Epicenter	No of Ev		No of Sta		Cluster Geometry			Outlier[a]	No of GT Cand[b]	
		Fix	Free	<20°	>20°	Diameter (km)[c]		SD (km)[d]			
France, Annecy	45.94 6.09	1	11	73	0	11.2	11.3	2.1 2.6	9.6	11	10
Italy, Umbria-Marche	43.01 12.80	1	64	259	102	47.7	45.2	6.4 6.2	8.1	61	7
Poland, Lubin	51.49 16.09	9	37	131	9	36.6	15.6	4.7 2.1	5.9	37	34
Poland, Silesia	50.35 18.82	1	23	31	1	24.4	23.9	3.8 3.8	6.9	0	0
Slovenia, Krm Mountains	46.31 13.63	1	21	115	0	18.2	12.1	2.5 2.3	4.2	21	13
Spain, Jayena	36.96 -3.78	1	17	58	2	43.1	37.1	4.6 4.5	4.4	12	0
Spain, Loja	37.21 -4.20	4	29	38	0	31.3	15.7	4.4 1.9	7.3	27	27
Spain, Montellano	36.99 -5.52	1	13	28	0	39.0	45.7	9.3 12.7	2.8	0	0
Spain, Murcia	38.12 -1.48	2	7	23	0	29.8	34.2	6.2 5.0	6.0	0	0
Switzerland, Engelberg	46.72 8.42	1	7	13	0	31.0	31.2	8.4 6.6	5.7	6	0
Turkey, Adana	36.88 35.50	2	14	65	42	41.3	52.7	6.8 9.6	11.4	5	1

a. Per cent arrivals that were rejected as outliers in the JHD.
b. Number of events with semi major error ellipse axis < 5 km (left column); right column gives number of events that also are within 5 km of reference event used to constrain JHD.
c. Diameter spanned by epicenter before (left column) and after (right column) JHD was applied.

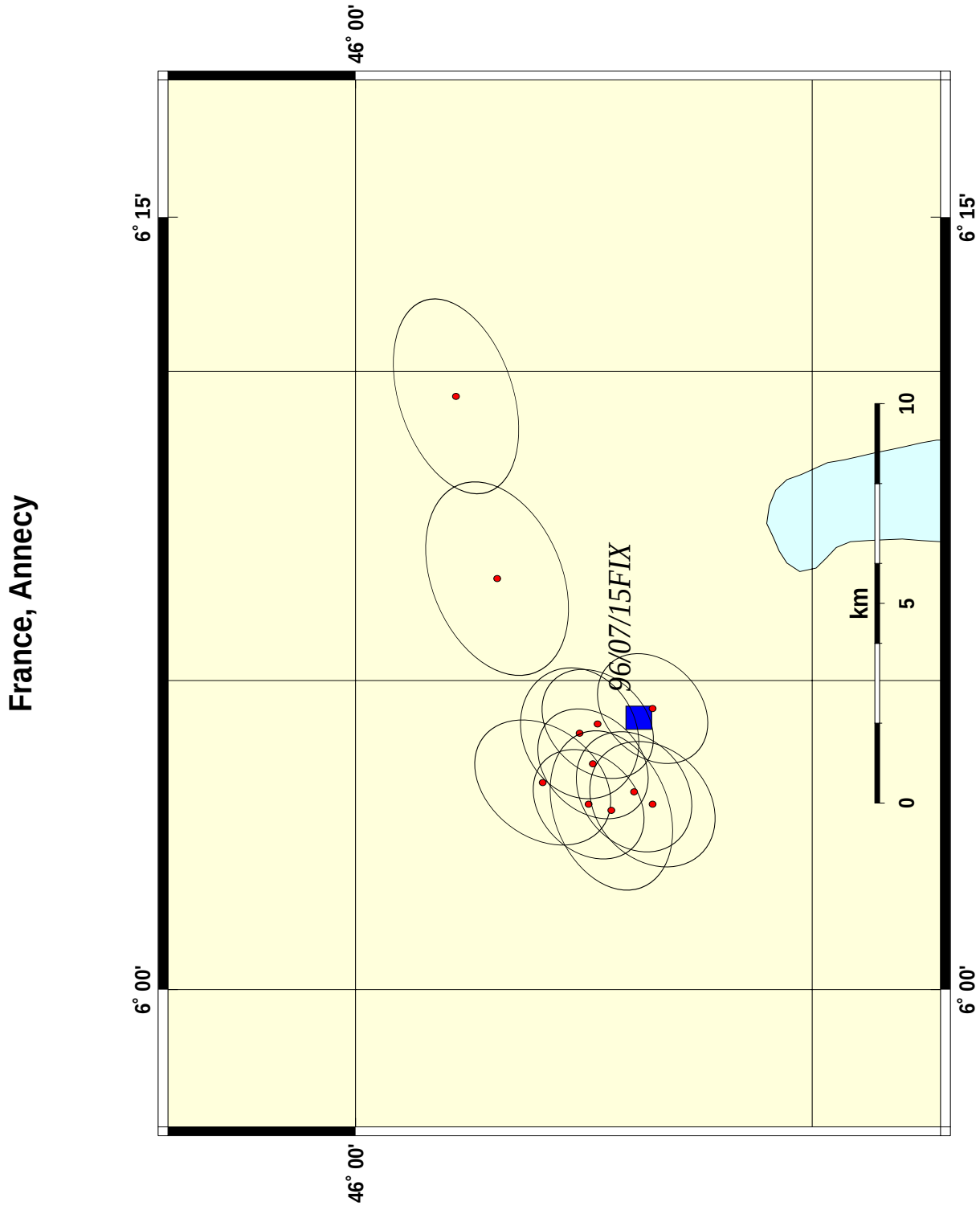
d. Standard error of distances from center of event cluster before (left column) and after (right column) JHD was applied.

Table 2: Candidate Reference Events

Cluster	Date/Time	Hypocenter	Error Ellipse	Ndef	Azgap
France, Annecy	1996/07/23 02:50:30.9	45.935 6.091 2.0	1.6 1.2 55	68	31
	1996/07/23 04:08:41.0	45.948 6.073 2.0	1.6 1.2 55	67	32
	1996/07/20 22:04:33.9	45.949 6.060 2.0	1.6 1.2 54	66	32
	1996/07/15 05:46:12.5	45.947 6.086 2.0	1.6 1.2 53	65	37
	1996/08/01 06:00:11.1	45.939 6.064 2.0	1.7 1.3 61	48	49
	1996/07/15 00:28:51.1	45.951 6.083 2.0	1.8 1.4 72	43	57
	1996/10/11 04:36:07.0	45.935 6.060 2.0	1.8 1.4 57	36	49
	1995/08/02 03:05:17.3	45.959 6.067 2.0	1.9 1.4 46	34	61
	1996/07/15 06:44:10.3	45.944 6.058 2.0	2.2 1.4 72	31	89
Italy, Umbria-Marche	1997/10/06 23:24:52.4	43.000 12.766 10.0	2.0 1.1 23	293	37
	1997/09/03 22:07:28.6	42.981 12.769 10.0	2.2 1.2 21	213	107
	1997/10/16 12:00:30.8	42.988 12.778 10.0	2.2 1.2 22	179	43
	1997/09/26 13:30:52.0	42.993 12.831 10.0	2.4 1.3 23	148	67
	1997/09/07 23:28:04.7	42.980 12.755 10.0	2.4 1.3 20	146	119
	1997/10/07 02:39:16.1	43.010 12.791 10.0	3.5 2.1 -5	72	170
	1997/09/26 13:52:54.1	42.972 12.796 10.0	3.7 2.6 6	48	135
Slovenia, Krm Mountains	1998/04/12 22:13:48.3	46.338 13.636 7.5	1.7 1.3 40	98	25
	1998/04/15 22:42:10.5	46.310 13.666 7.5	1.8 1.3 38	82	27
	1998/06/10 23:32:41.5	46.317 13.638 7.5	1.9 1.4 36	74	38
	1998/04/12 16:15:39.7	46.327 13.603 7.5	1.9 1.4 37	71	37

Table 2: Candidate Reference Events

Cluster	Date/Time	Hypocenter	Error Ellipse	Ndef	Azgap
Slovenia, Krm Mountains	1998/04/12 20:54:01.3	46.338 13.623 7.5	2.0 1.5 35	51	39
	1999/07/25 21:07:11.6	46.318 13.621 7.5	2.3 1.5 25	49	52
	1998/04/13 03:23:27.1	46.316 13.603 7.5	2.3 1.5 25	48	53
	1998/04/12 12:43:55.2	46.325 13.619 7.5	2.1 1.6 35	43	38
	1998/04/12 14:24:08.6	46.293 13.645 7.5	2.4 1.6 30	34	60
Spain, Loja	1998/04/15 16:54:51.8	37.224 -4.198 7.7	2.3 1.2 -27	27	105
	1998/04/13 22:55:12.9	37.209 -4.189 7.7	2.3 1.2 -23	26	107
	1998/04/12 07:42:39.8	37.204 -4.206 7.7	2.4 1.2 -20	26	108
	1998/04/12 13:10:37.6	37.207 -4.203 7.7	2.5 1.2 -24	26	107
	1998/04/13 17:11:52.2	37.224 -4.201 7.7	2.1 1.3 -25	25	105
	1998/04/12 04:52:57.5	37.193 -4.192 7.7	2.5 1.5 -21	24	109
	1998/04/13 15:59:04.4	37.224 -4.195 7.7	2.2 1.3 -25	23	105
	1998/04/15 23:51:52.7	37.248 -4.211 7.7	2.4 1.4 -32	20	103
	1998/04/12 12:52:40.4	37.224 -4.207 7.7	2.5 1.3 -24	20	106
	1998/04/20 23:03:54.7	37.217 -4.193 7.7	2.3 1.4 -30	19	106
Turkey, Adana	1998/07/04 09:24:22.9	36.864 35.479 37.3	4.4 1.6 67	65	108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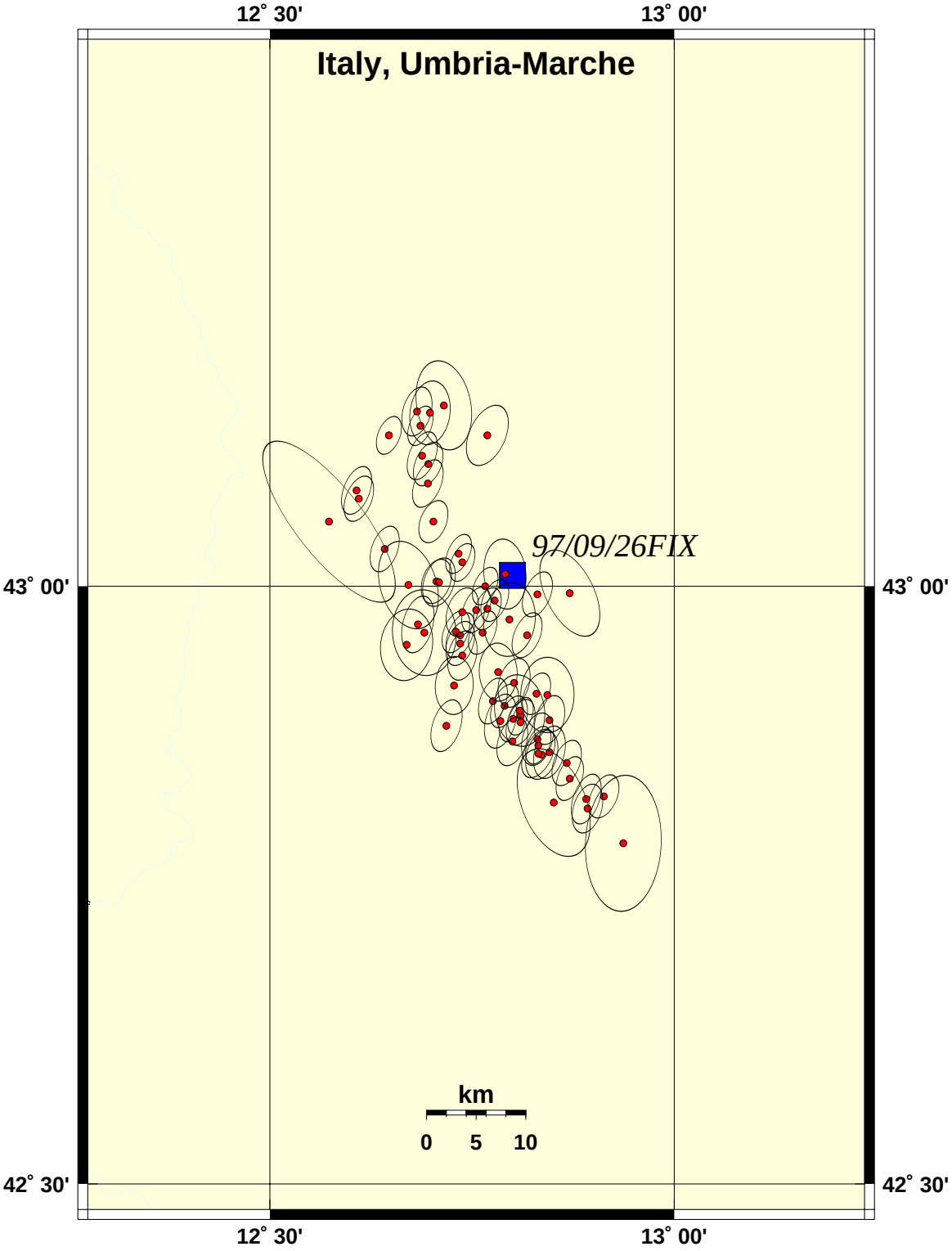
6° 00'
96/07/15FIX
km
0
5
10


12° 30'
13° 00'
Italy, Umbria-Marche
97/09/26FIX
43° 00'
43° 00'
km
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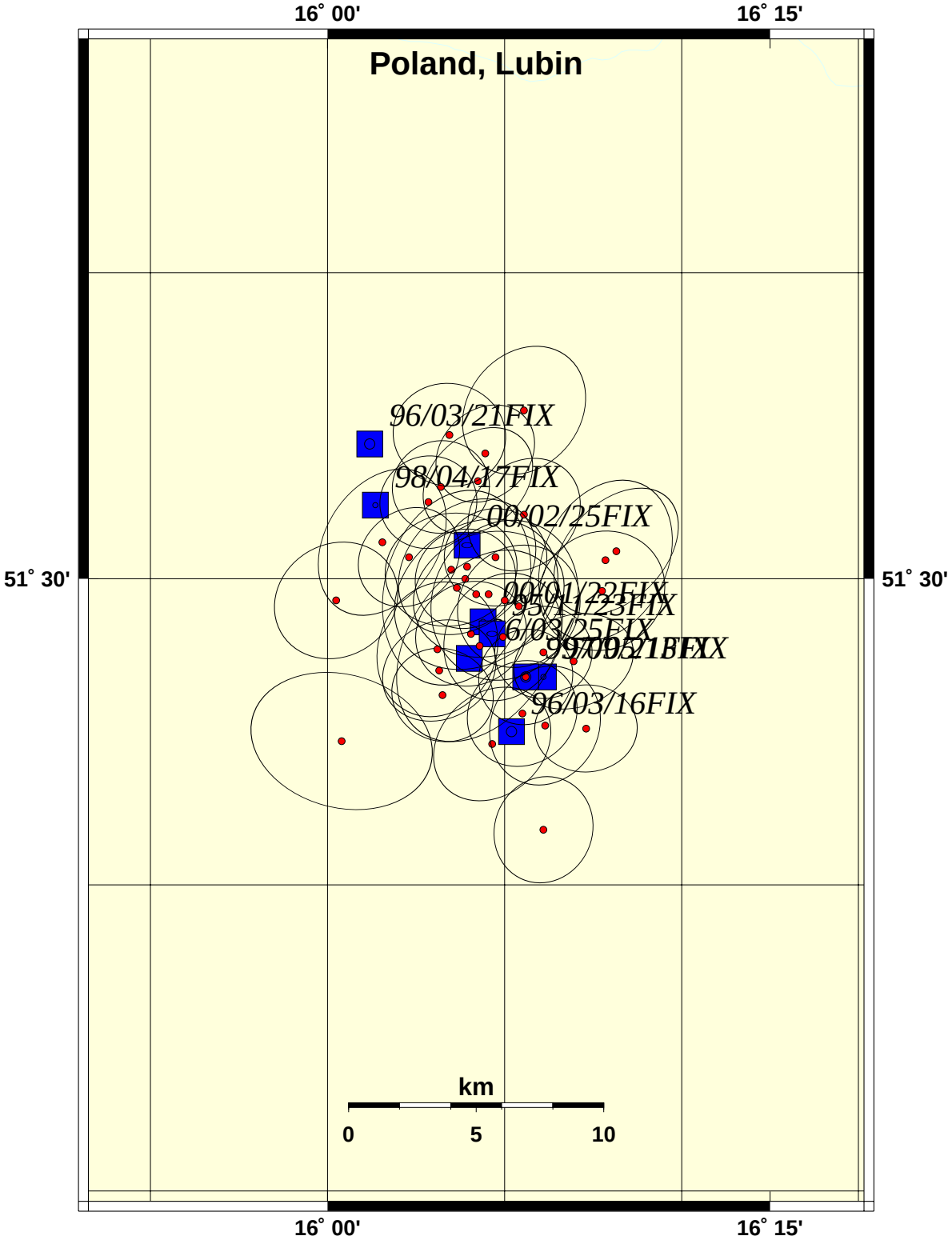
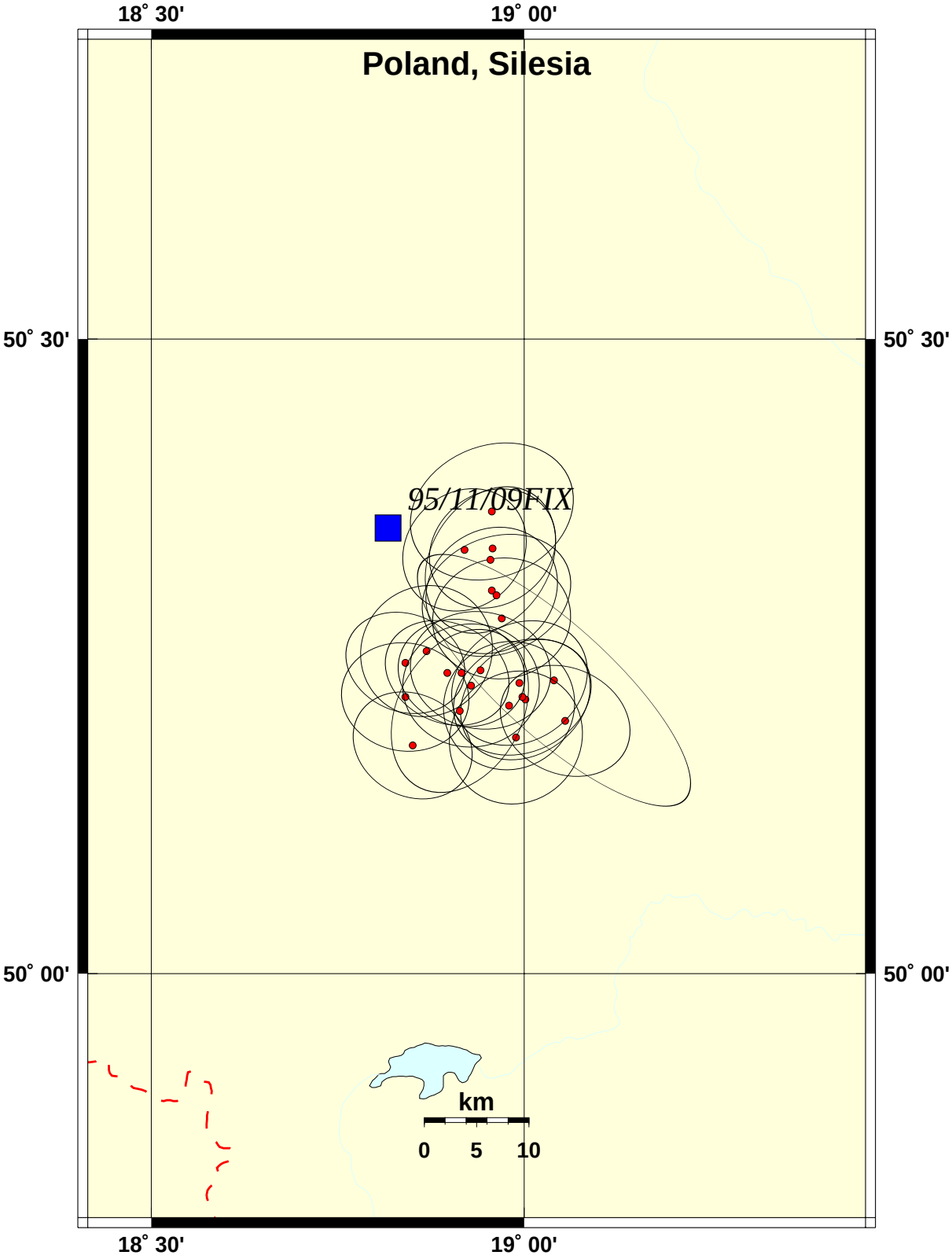
42° 30'
42° 30'
12° 30'
13° 00'


16˚ 00'
16˚ 15'
Poland, Lubin
51˚ 30'
51˚ 30'
96/03/21FIX
98/04/17FIX
00/02/25FIX
00/01/22FIX
95/11/23FIX
96/03/25FIX
96/03/16FIX
km
0
5
10
16˚ 00'
16˚ 15'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18° 30'
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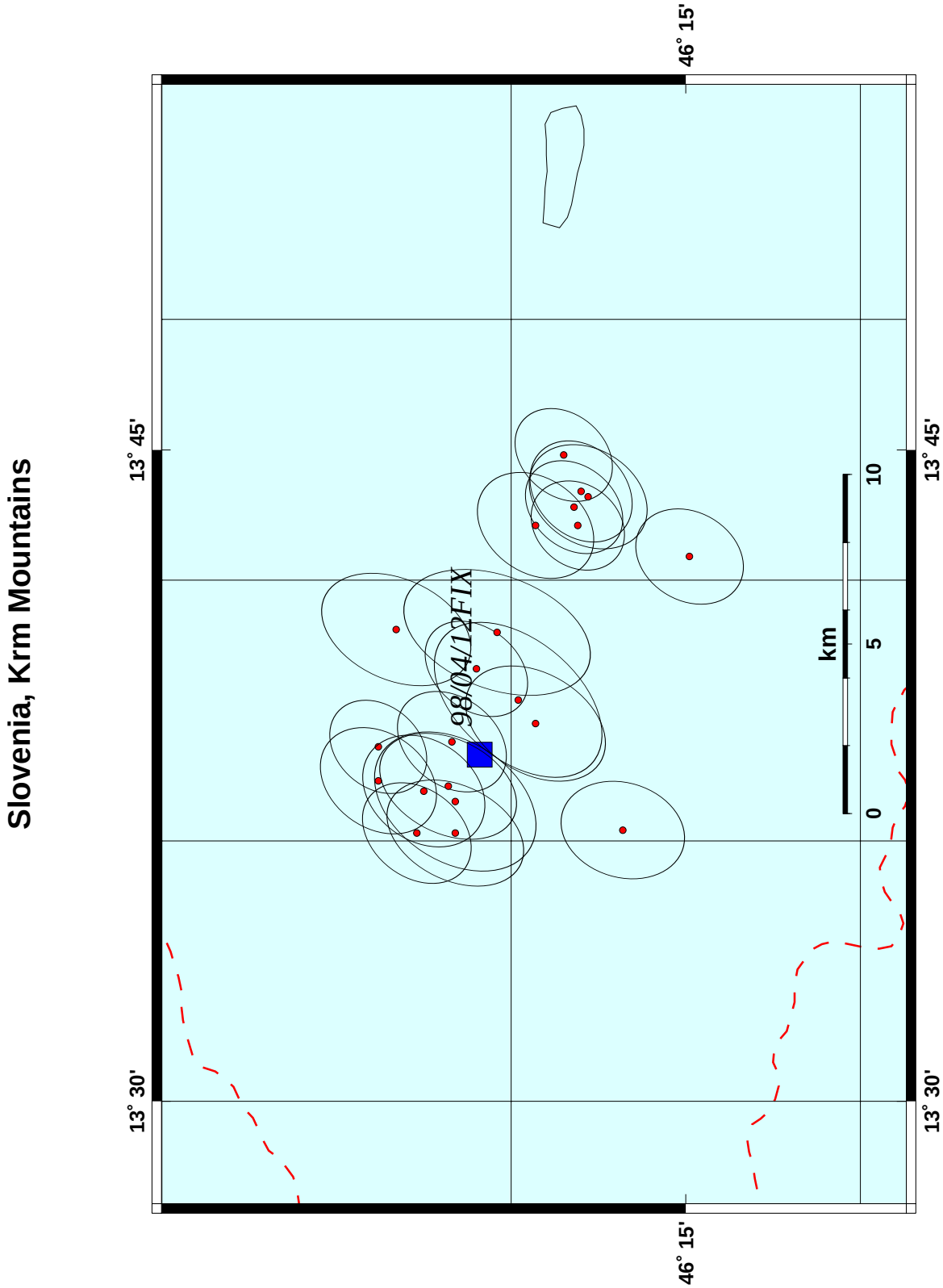
50° 30'
50° 00'
95/11/09FIX
km
0
5
10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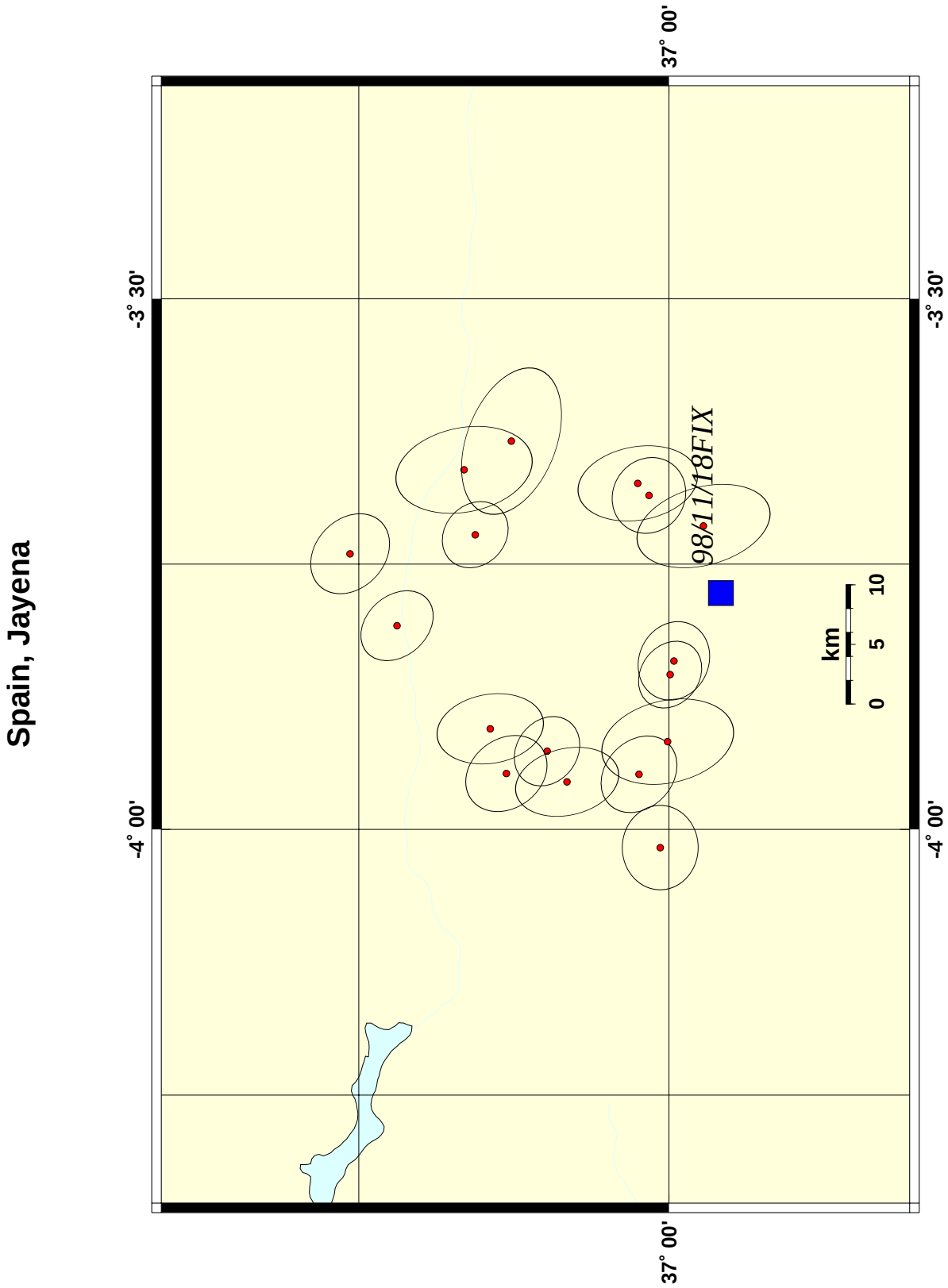
46° 15'
13° 45'
13° 30'
98/04/12FIX
km
0
5
10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km
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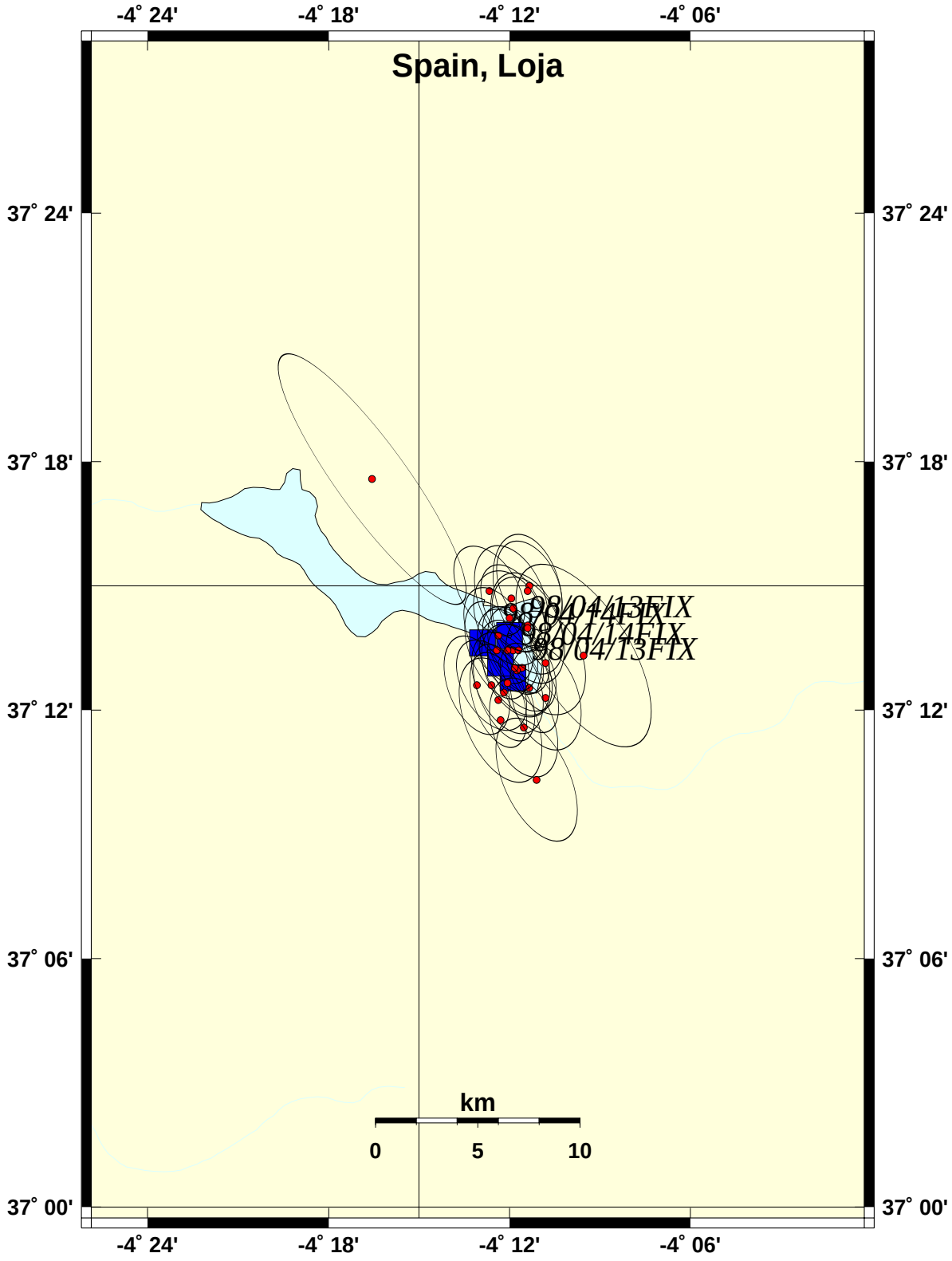
5
10


Spain, Loja
-4° 24'
-4° 18'
-4° 12'
-4° 06'
37° 24'
37° 18'
37° 12'
37° 06'
37° 00'
98/04/13FIX
98/04/14FIX
98/04/14FIX
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km
0
5
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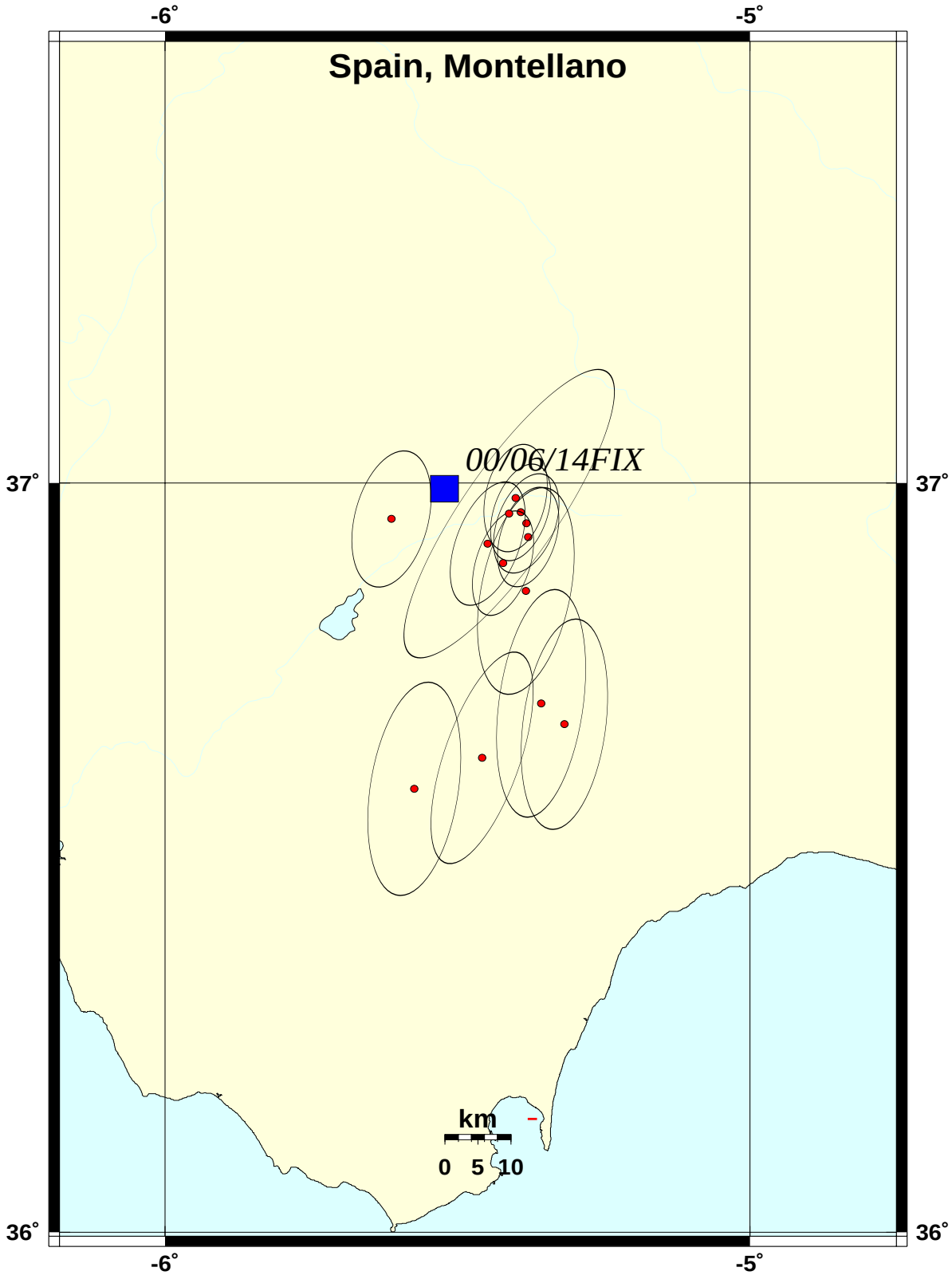
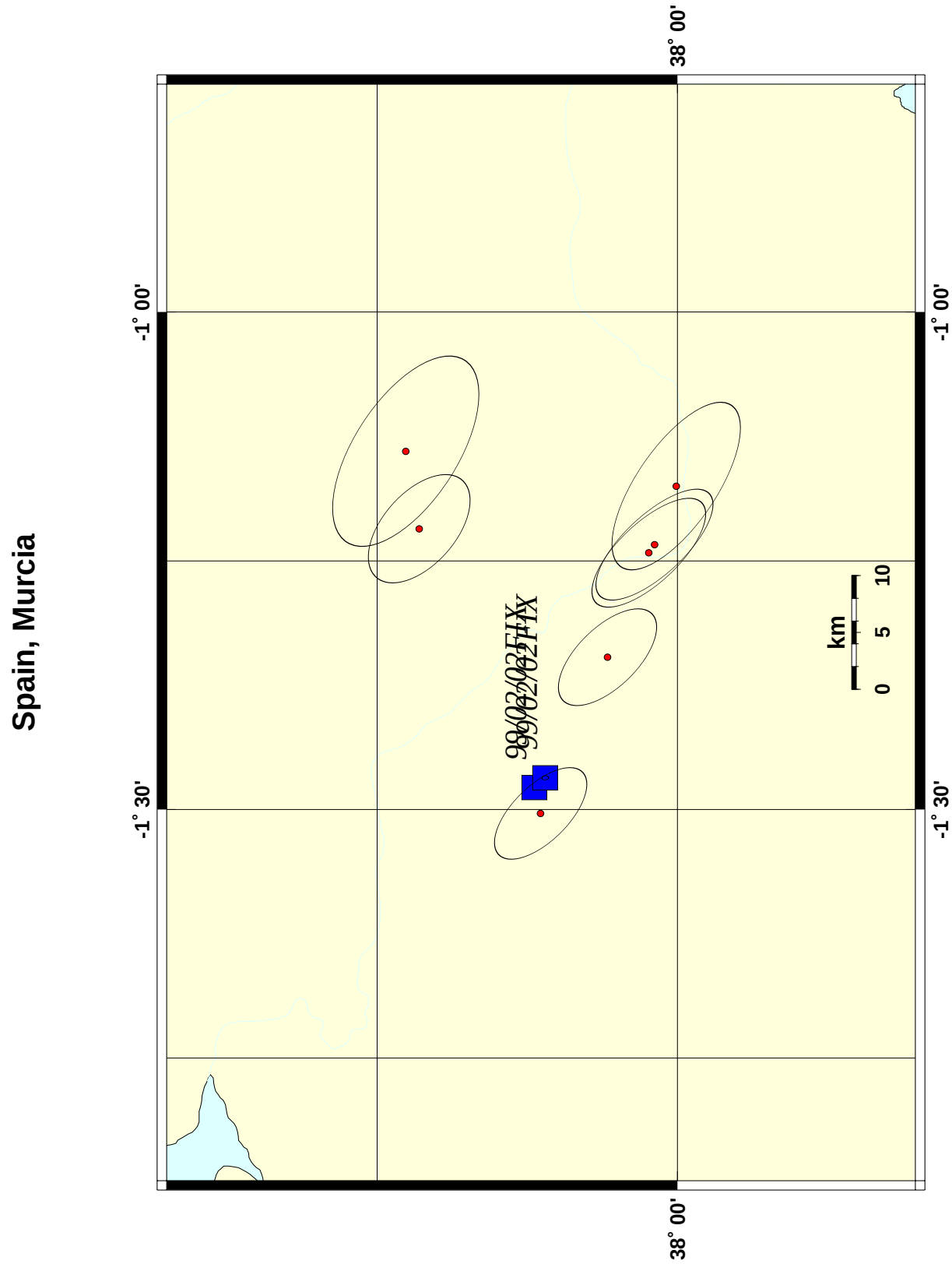

Spain, Montellano
00/06/14FIX
-6°
-5°
37°
36°
km
0 5 10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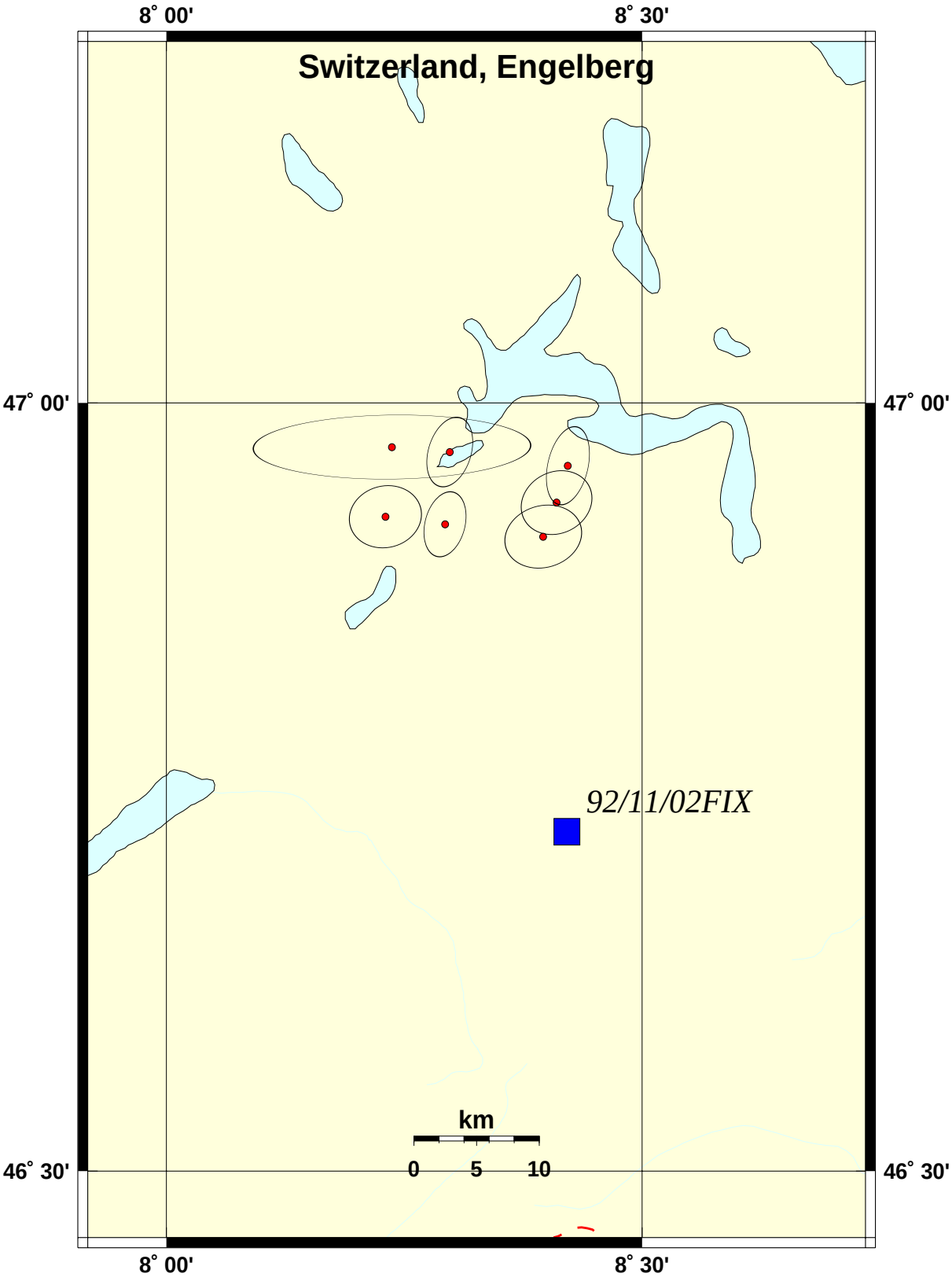
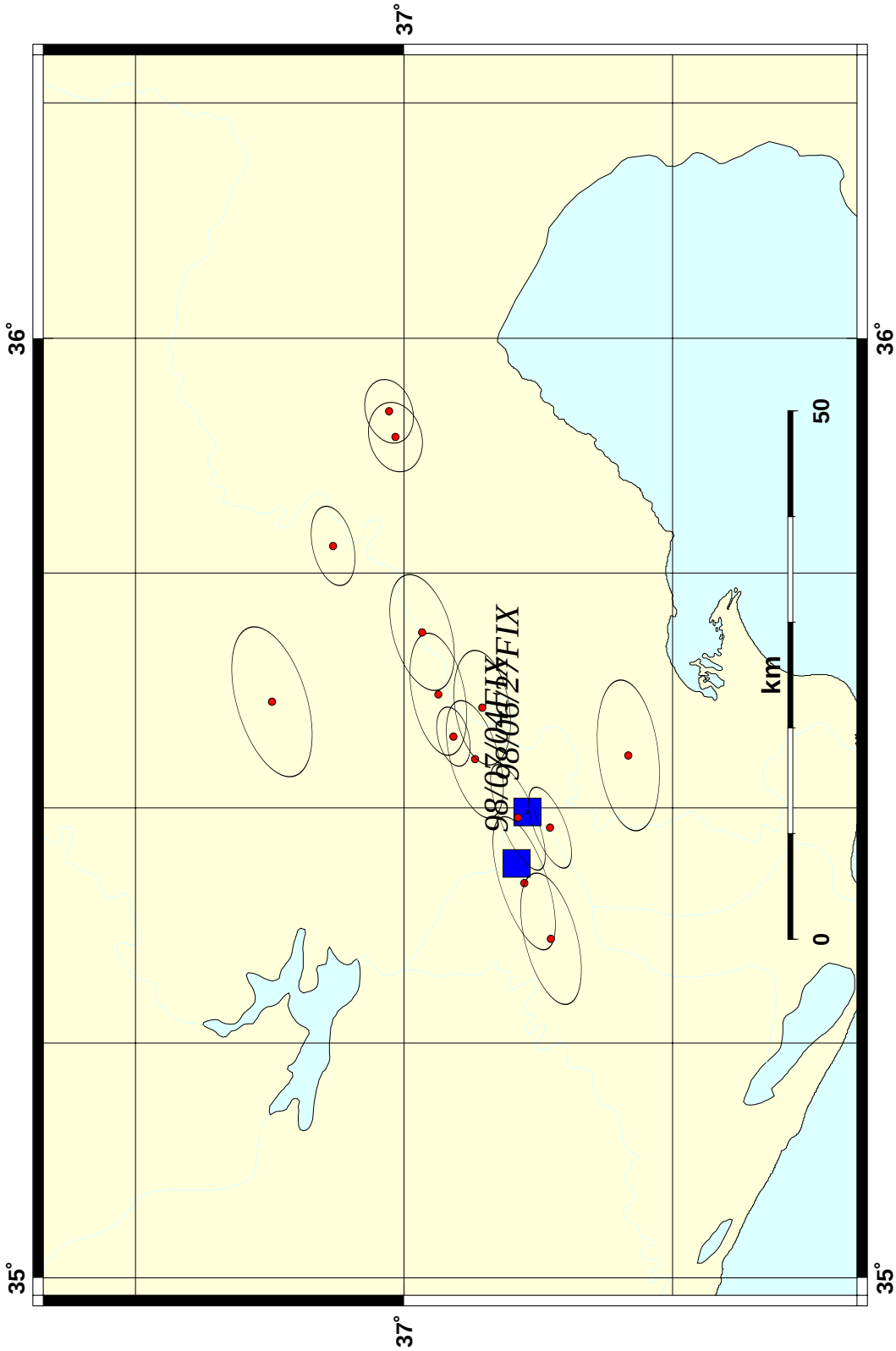
38° 00'
-1° 00'
-1° 30'
km
0
5
10


Switzerland, Engelberg
8° 00'
8° 30'
47° 00'
46° 30'
92/11/02FIX
km
0
5
10

Turkey, Adana